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Trees for Food and Timber: are community interests in conflict with those of timber concessions in the Congo Basin?

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Abstract

Much of the Congo Basin is managed for timber from dozens of species. More than 60% of them also produce nontimber products, including foods gathered by local people. For five multiple use tree species in Cameroon, Democratic Republic of Congo (DRC) and Gabon (*Entandrophragma cylindricum*, *Baillonella toxisperma*, *Erythrophleum suaveloens*, *Dacryodes buettneri* and *Gambeya lacourtiana*), we studied gathering and consumption by communities, the volumes of edible caterpillars hosted, the densities of trees around villages and in concessionsand the impacts of timber harvesting on the trees and their population viability. In addition, we studied the consumption of forest foods and the nutritional values of fruits and seeds of various tree species.We found that villagers walked up to more than five km during day trips to collect fruits or caterpillars, gathering from concessions if the village was within or near it. When food resources were gathered from trees smaller than the cutting diameter (which varied by country and by species), there was no conflict between gathering tree foods and timber harvesting. However the volume of edible caterpillars hosted by an individual tree increased with diameter and the most productive trees were those of commercial size. Tree fruits and seeds provided fats, vitamins and minerals that complement agricultural foods. Densities of commercial sized trees of *B. toxisperma*, valued for its edible oil, were higher around villages than in concessions. The proportion of commercial trees harvested for timber varied from less than 3% to more than 50%, depending on the species. Different species had different geneflow distances, meaning that viable regeneration could be retained with residual adults at different maximum distances. *E. cylindricum* had more effective dispersal than *E. suaveolens*. The production of timber and nontimber products can be sustained from the same concessions, for different stakeholders, with appropriate practices and arrangements.

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Keywords: Congo Basin, timber concessions, nontimber forest products, food trees, logging impacts

Introduction, scope and main objectives

The Congo Basin forest, the second largest rainforest in the world, is at the centre of the debate on reconciling timber and non-timber production The livelihoods of over 50 million people depend on these forests (Feintrenie 2014, Gatti et al. 2014, Tieguhong and Ndoye 2007, Nasi et al. 2011, Ndoye and Tieguhong 2004) . The Congo Basin forest is also a vital economic resource in the region: over 40% of its 200 million hectares are allocated to commercial logging leases. A collaborative, multidisciplinary research project was carried out to document the degree to which local populations depend on forest resources, particularly for food, the nutritional value of those foods, whether people obtained those resources from timber concessions, and the effect of logging on the abundance and future availability of those resources. The study was carried out in and around two concessions each in Cameroon and the Democratic Republic of Congo (DRC) and one in Gabon (Figure 1).

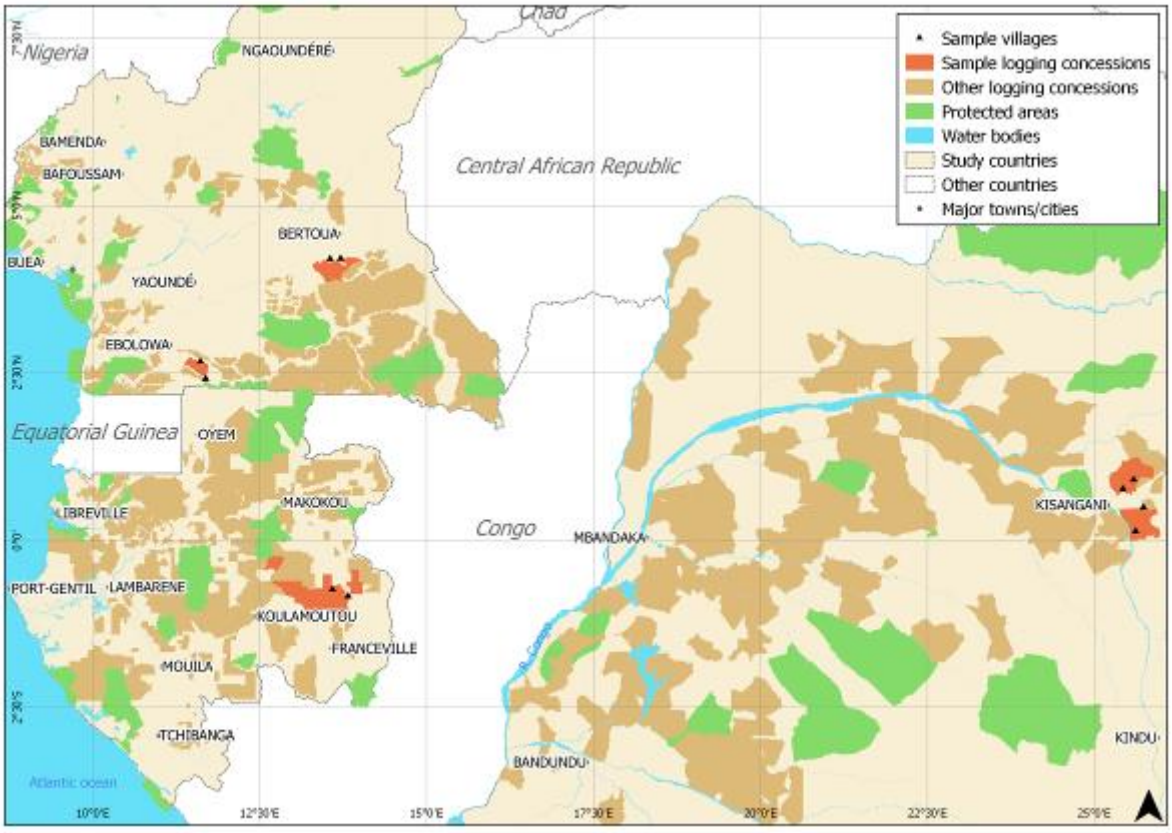


Figure 1. Sample concessions in Cameroon, Gabon and Democratic Republic of Congo

Methodology/approach and initial results

Seven studies were carried out as described below.

1. The consumption of tree and forest foods

In 34 communities living within or adjacent to the six forest concessions, 724 households were selected using a cluster sampling technique involving one stage of purposeful selection and one stage of randomization. Food consumption pattern data was collected on a quarterly basis using a validated food-frequency questionnaire and questions on consumption of forest foods assessed the frequency of consumption of the thirteen FAO recommended food groups (FAO, 2012).

2. Nutritional values of tree foods

Samples in triplicate of fresh, mature and ripe fruits were collected from 10 trees of each species from Gabon and Cameroon. At the nutritional laboratory of Yaoundé I University they were analysed for macronutrients, micronutrients (vitamins and minerals) and bioactive compounds.

3. Selection of food-producing timber trees for more intensive study

Five tree species were selected for more intensive study because they were important for timber, produced locally important food, and occurred within the selected concessions.

4. Participatory mapping of food collection trees

To determine whether villagers obtained food resources from trees growing in neighbouring concessions, a female or a male researcher accompanied a different female or male collector, respectively, each day for 5 days to the trees of the selected species from which they obtained food resources around each of 2 sample villages within or near each sample concession. Trees were measured and their GPS coordinates were overlain on concession maps and R and QGIS software were used to analyse the distances travelled to each tree.

5. The density of food trees around villages and on timber concessions

Tree densities around villages were evaluated along three transects from the village towards the concession, oriented at 45°one from the other, extending 10 kms. Sample plots of five ha (100 m x 500 m) were laid out alternately on one side of each transect or the other. A total of 21 five-hectare plots were established around each of the four sample villages at a constant sampling intensity of 0.5%. To determine whether the density of these species was significantly reduced by timber harvesting on the concessions, sampling was carried out on the annual cutting areas of 2012 shortly after the harvest. Sampling was stratified using the companies' 25 ha inventory plots: five 25-ha inventory plot each five ha sample plots all individuals $\geq$ 20 cm dbh of the sample species were identified and their diameters measured at 1.3 m height or 10 cm above buttresses. In addition, stumps of these species, revealing the impact of the 2012 harvest, were identified and noted.

6. Quantification of caterpillar production

Like other edible insects, caterpillars are very rich in proteins. Flour made from the caterpillar Imbrasia oyemensis contains 58 % protein and 24 % fats (Amon Aphael, et al., 2009) while Cirina forda contains 14% protein, a proportian similar to beef. Caterpillars are also rich in micronutrients, providing magnesium and iron that is essential for the nutrition of pregnant women and babies (FAO, 2013). To determine the yield of edible caterpillars on timber tree species, yields were quantified for 170 trees of E. suaveolens and 50 trees of E. cylindricum between 20 cm and 190 cm in diameter. Around each tree, a ditch 20 cm deep and 20 cm wide was dug at the edge of the canopy. From July to September of two successive years, caterpillars were collected twice a day from these ditches and weighed. Production by diameter category was analyzed using regressions and Wilcoxon tests.

7. Evaluation of patterns of gene flow

Patterns of gene flow (mating system and pollen- and seed-mediated gene dispersal) were estimated through molecular approaches for *B. toxisperma, E. cylindricum and E. suaveolens*. Leaves or cambium were sampled from seeds, seedlings and adults of each species, which were then genotyped at nuclear microsatellite markers (Duminil et al., 2011; Garcia et al., 2004; Ndiade Bourobou et al., 2009). Relying on genotypes data of progeny arrays, the mating system (levels of self-reproduction) was estimated using MLTR v.3.2 (Ritland, 2002). Pollen- and seed-mediated gene dispersal were estimated using NM+ (Chybicki and Burczyk, 2010).

Results

1. Consumption of tree foods

Households consumed tree foods five times a week, on average, butpatterns varied among the three countries. In DRC, households complemented agricultural foods by consuming wild fruits and edible caterpillars as well as bush meat. In Cameroon households also complemented agricultural foods with wild fruits and consumed low quantities of bush meat. In Gabon, households consumed forest fruits (ozigo pulp and bush mango seeds) as well as bushmeat (antelope, porcupine, wart hog, rats and wild birds). They also consumed processed foods of high lipid content, such as margarine, butter and protein-rich cheese, as well as agricultural foods.

2. Nutritional values of tree foods

Analyses were carried out of the fruits or seeds of *Trichoscypha abut, Pentaclethra macrophylla and B. toxisperma* in Cameroon and of *G. lacourtiana, D. buettneri, Panda oleosa, Poga oleosa, Pseudospondias spp., Afrostyrax lepidophyllus,* and *Antrocaryon klaineana* in Gabon; no nutritional analysis was done in DRC because of the difficulty getting samples to a laboratory. Forest tree foods provide significant amounts of macronutrients, micronutrients and bioactive compounds. *T. abut* fruit was an exceptional source of bioactive compounds as well as vitamin C (80mg/100g) while *P. macrophylla* seeds were a rich source of fat (39%) and protein (16%) as well as vitamin E (19 mg/100g). *B. toxisperma* fruit has high carbohydrates (90%), potassium (28 mg/100g) and calcium (38 mg/100g). The fruit of *D. buettneri* was a good source of lipid, with a fat content of 53%, while the fruits of *G. lacourtiana* were high in carbohydrate (80%), potassium (715 mg/100g), calcium (378 mg/100g), phosphorous (232 mg/100g), and magnesium (181 mg/100g). *Poga oleosa* was high in potassium (241mg/100g), phosphorous (232 mg/100g), and iron (21 mg/100g).

3. Selection of food-producing timber trees for more intensive study

We focused on the following five species: moabi (*Baillonella toxisperma*), a valuable timber tree that also produces an edible fruit and oil, in Cameroon; sapelli (*Entandrophragma cylindricum*), important for timber and host of the edible caterpillar *Imbrasia oyemensis*, in Cameroon and DRC; tali (*Erythrophleum suaveolens*), a timber tree that hosts the edible caterpillar, *Cirina forda*, in both Cameroon and DRC; and in Gabon, where neither of those species occurred at sufficient densities to study, ozigo, *Dacryodes buettneri* and abam, *Gambeya lacourtiana* (*syn. Chrysophyllum lacourtianum*) both producers of edible fruits.

4. Participatory mapping of food collection trees

On one-day collection trips people walked an average of 2.24 km (±1.21 km), ranging from 0.06 to 6.24 km, from their villages to collect food resources (caterpillars from sapelli and tali, fruits from moabi, ozigo and abam). Women, men and children collected tree foods, usually in mixed groups. Of the trees visited, 72% were within logging concessions (reflecting the large number of trees recorded

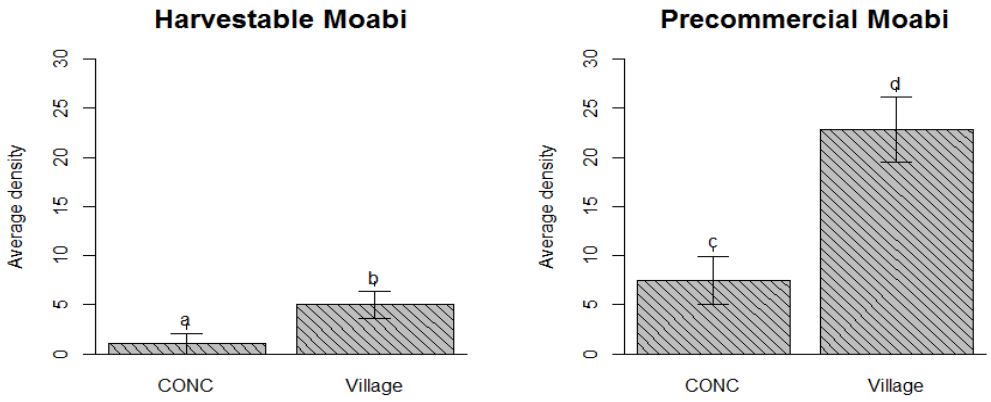
in the four sample villages in the DRC, inside logging concessions). Most trees were larger than the felling diameter, meaning they could be felled for timber by the concession owner (Table 1).

	Tree location in relation to logging concession (# of trees)		**DBH in relation to felling diameter (# of trees)**		**Distance between the village and the trees (km)**			
	Outside	Inside	< felling diameter	> felling diameter	Average	St. Dev.	Min.	Max.
Total	200	524	169	555	2.24	1.21	0.07	6.24
Cameroon	161	27	31	157	2.7	1.42	0.15	6.24
DRC	0	402	88	314	2.18	0.99	0.23	5.87
Gabon	39	95	50	84	1.78	1.26	0.07	4.46
Moabi	52	10	12	50	2.48	1.26	0.41	6.06
Sapelli	59	74	67	66	2.65	1.32	0.23	6.24
Tali	50	345	40	355	2.22	1.08	0.15	5.87
Ozigo	24	51	48	27	2.03	1.34	0.1	4.46
Abam	15	44	2	57	1.46	0.99	0.07	4.34

Table 1. Locations and distances to different species and sizes of trees visited by collectors to obtain foods

5. The density of food trees around villages and on timber concessions

In DRC, the density of sapelli and tali trees around the villages was not significantly different from their density on concessions, because the villages are located within the concessions.. In Cameroon, moabi trees of both precommercial and harvestable sizes were more abundant around villages while precommercial tali were more abundant on concessions (Fig 2). However, no moabi stumps were found on sample plots in the 2012 cutting area of the two concessions, indicating that timber companies had respected their agreement with communities not to fell these trees.



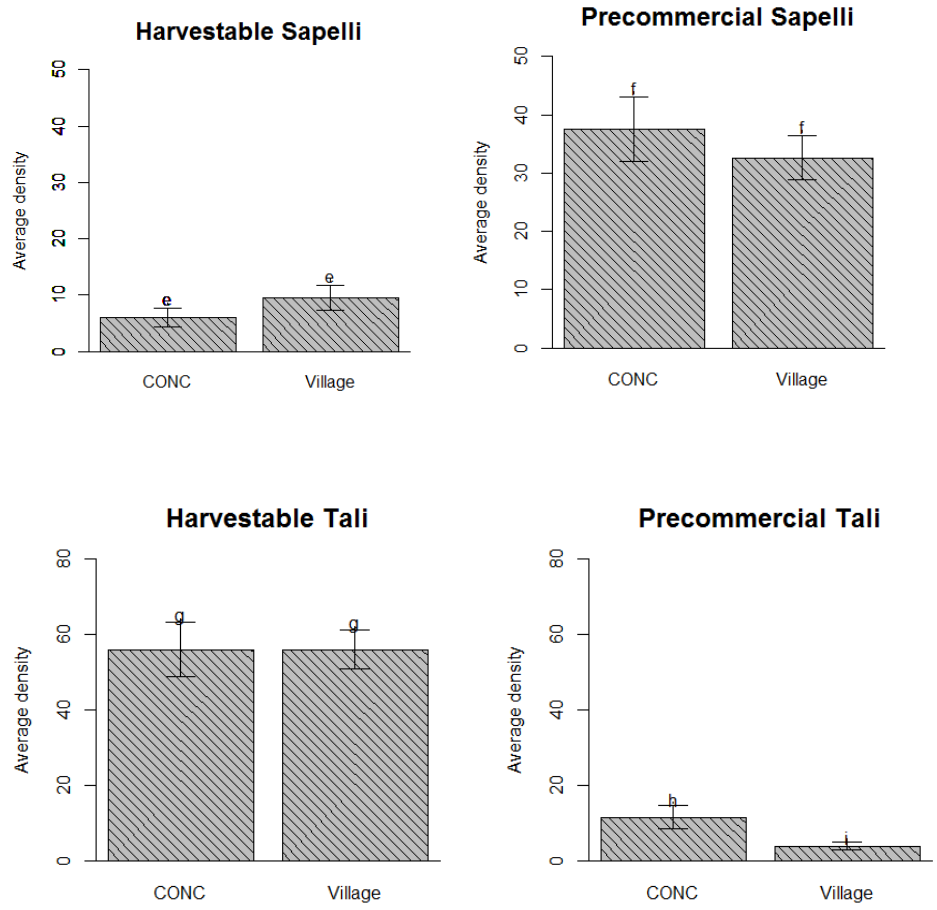


Figure 2..Density per 100 ha of individuals of Sapelli, Moabi and Tali, harvestable and precommercial, on concessions and around villages in Cameroon. Cutting diameters: Moabi ≥ 80 cm, Sapelli ≥ 100 cm,Tali ≥ 60cm. Different letters indicate statistically significant differences between bars.

In Cameroon, 6 – 11% of harvestable tali trees were extracted by concessionaires as compared to 21%-50% of sapelli trees. Tali is harvested to order whereas sapelli has practically unlimited demand. The fact that not all harvest-size individuals were extracted may reflect quality requirements, but also the fact that access to some portions of the concession is constrained by flooded lowlands or steep slopes. These areas are protected from harvesting, and are also inaccessible. Furthermore, regulations require that seed trees be left standing.

6. Quantification of caterpillar production on timber trees

Larger trees hosted larger quantities of edible caterpillars. Sapelli trees of commercial size (> 80 cm dbh) produced six times as many caterpillars as precommercial trees: 10.9 ± 0.3 kg/tree of *I. oyemensis* as compared 1.1± 0.6 kg/tree. Commercial-sized tali trees (> 60 cm dbh) yielded 8.2 ± 0.1 kg/tree of *C. forda* as compared to 5.5 ± 0.1 kg/tree for precommercial trees (Figure 2). Given the density and size classes of trees estimated around the villages studied, sapelli trees provided approximately 1.8 kg/ha of *I. oyemensis* caterpillars and tali trees provided about 4.8 kg/ha of *C.forda* caterpillars each season.

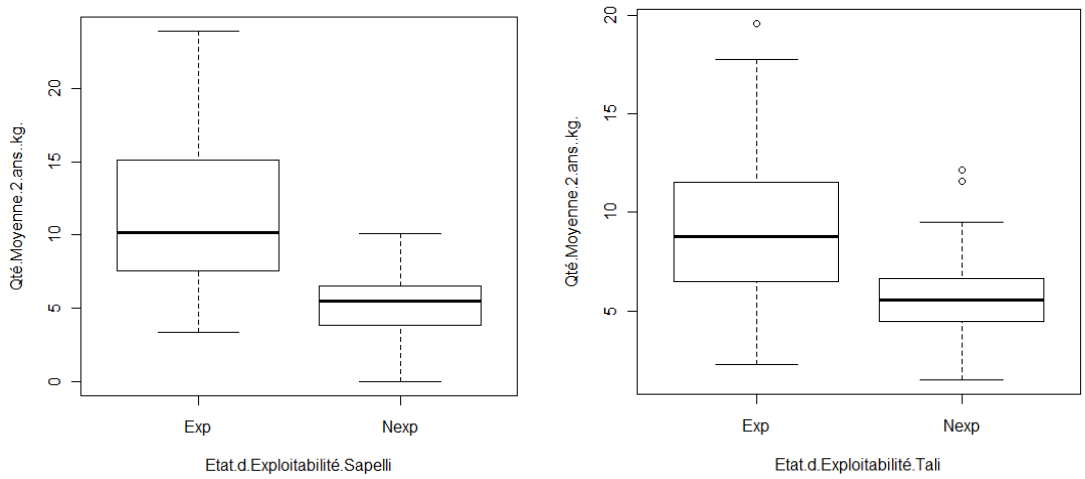


Figure 3. Average annual yield of caterpillars on trees of Sapelli (left) and Tali (right) of exploitable and pre-commercial (Nexp) classes.

7. Evaluation of patterns of gene flow in three tree species

Each species presented idiosyncratic patterns. Levels of self-pollination were found to be particularly high in *E. suaveolens* and *B. toxisperma* (20% and 27% respectively) and relatively low in *E. cylindricum* (about 7%). The mean pollen dispersal distance for *B. toxisperma*, *E. cylindricum* and *E. suaveolens* was found to be about 650 m, 500m and 350m, respectively. Gene dispersal through seeds was particularly important in *B. toxisperma*, which is naturally dispersed by elephants, with a mean distance of 1000 m. Seed dispersal was relatively limited in *E. suaveolens*, with a mean distance of 200 m. Estimates of seed dispersal distance (by wind) in *E. cylindricum* was similar to the pollen-dispersal distance, with a mean of 600 m.

Discussion

Households living on or in the vicinity of timber concessions all consume forest and tree foods. Fruits and seeds as well as caterpillars (particularly in Cameroon and DRC) provide protein, fats, vitamins and minerals that complement agricultural staples in their diets. It was noteworthy that in Gabon households had started to transition from foods they grew or collected to purchased processed foods with added sugar and fat. According to Steyn et al. (2001), such changes have contributed to the dramatic emergence of obesity and associated non-communicable diseases (NCD).

In all three countries, local people collected foods from trees within concession boundaries. Harvesting nontimber products from trees that have not yet reached commercial timber size is compatible with timber harvesting. Though their production per tree is lower, smaller trees are more abundant per unit area. Trees within a certain radius of villages (about 6 km) are probably the most important for villagers, as they typically travel on foot (though motorcycles are being used by some to go further, where roads provide access). Villagers' rights to meet their subsistence needs from the forest in timber concessions are recognized by law. However, they are not allowed to commercialize these resources, and some reported having fruits or other products confiscated by forest guards (not concessionaires) if they tried to collect and transport large quantities for sale.

Both caterpillars and fruits are more abundant on large trees with expansive canopies This means that timber harvesting removes the trees that have the highest yields. Other studies carried out in Cameroon showed a reduction in consumption of caterpillars by local people after the felling of their

host trees by a timber company (Asseng Ze 2008; Tieguhong and Ndoye 2007; Ndoye and Tieguhong 2004). However, when large trees are either inaccessible or have poor timber quality and are left standing, as we observed in this study, they continue to provide forage for caterpillars, and sources of fruits that feed the local population. One of our collaborating concessions, as well as others in Cameroon, agreed with villagers to stop felling Moabi due to the value of the tree to local communities. In Gabon, Ozigo is one of the fruit producing species for which the government has recently suspended permission for timber harvesting. It's noteworthy, though that the majority of trees from which fruits were collected during this study were smaller than the former minimum felling diameter. This study was conducted in a logging concession which seeks to obtain certification for good management, and the concession operator has delineated community areas within the logging concession, to provide land for forest activities and agriculture. Most of the Abam (68%) and Ozigo (79%) that were recorded inside the logging concessions fell within these areas, and therefore they are available to the communities with no threat of logging by the concession operator. It would be useful to compare these results with the situation in another concession that is not as progressive.

In Cameroon, the majority of the collection trees were larger than their minimum felling diameter, but most of them were located outside logging concessions. They are nevertheless vulnerable to logging. In two cases these trees were located within a community forest and while this could be considered a safeguard, in Cameroon the main activity in community forests has been felling for timber production (Logo, 2003), and the benefits are commonly obtained only by individuals or specific groups, rather than the community as a whole (Ezzine de Blas et al., 2011; Ofoulhast-Othamot, 2014). Even when trees are within a close radius of the village, outside a concession or a community forest, there may be conflicts between villagers as to the best use of the tree, whether to sell it as timber or to retain it for its yield of nontimber products. When the nontimber benefit is a food product there is often a gender aspect to the preferences. It is women, for example, who produce the moabi oil; often men are more inclined to sell the tree for timber, which is one of the best options for obtaining significant quantities of cash quickly, if needed, for example for a health emergency. A significant illegal timber sector exists in Cameroon and Congo DRC, which is estimated to be larger than the export sector in terms of annual sawn wood production volume (Lescuyer et al., 2012), and Sapelli and Moabi are among the species felled by local timber producers (Levang et al. 2015).

Conclusions/outlook

Where nontimber products are obtained outside concessions or from trees that are below commercial size, or where commercial sized trees are not felled, there is no conflict between timber harvesting and gathering of nontimber products. Arrangements that consider the uses of non timber products from timber species by resident villagers can also forestall conflicts, either through agreements not to harvest those species (as agreed voluntarily by the concessionaires in Cameroon with regards to Moabi), or by regulation (as imposed by the government of Gabon with regards to Ozigo and Abam). However, even outside the concessions timber trees are not protected from felling. Internal negotiations among villagers seem important to allow for balancing the interests of those who want to harvest forest foods every year with those who seek a one-time windfall from selling a tree for timber of a tree.

Over the long term, the availability of these resources, both timber and nontimber, depends on successful regeneration. This study revealed that tree seeds resulting from from self-pollination do not survive, so defining minimum distances between parent trees that allow for cross-fertilization is important to ensuring the viability of regeneration. Because patterns of gene flow vary from species to species, the establishment of harvesting guidelines requires understanding species-specific patterns. More research on individual timber species is needed so that forest management practices can take into account the genetic aspects of sustainability.

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